# The Assessment of Exposure to Whole-Body Vibration and Noise in a Metal Processing Plant

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**Abstract**

*This study evaluates vibration and noise measurements performed at a metal processing plant from the perspective of occupational health and safety. A risk assessment study regarding exposure to vibration and noise was performed at the locations where technicians work in the plant. When the results were analysed, it was found that the technicians were exposed to whole-body vibration and that the noise levels were high in the production area. To determine the level of exposure to vibration and noise, a vibration- and sound-level measuring device was used to determine the vibration levels, equivalent noise levels, and peak sound pressures (Ppeak) along the x, y, and z axes to which the workers were exposed. The measured whole-body vibration personal exposure values were between 0.1–0.42 m/s², the personal noise exposure levels were between 64.9–98.7 dB(A), and the Ppeak values were between 95.2–120.5 dB(C). The whole-body vibration personal exposure values were below the limits imposed by national regulations, but the noise exposure values were above the limits at most of the sampling locations.*

**Keywords** – Metal processing plant, noise, vibration, occupational health and safety, risk assessment.

**1. Introduction –** Every worker has a right to work in a healthy and secure environment that is free of risks that threaten his/her physical and spiritual health. However, this notion has only recently emerged. To avoid risks in the workplace, the employer is not only required to provide protective equipment suited to the job but also to destroy or minimise risks at their sources. When it is not possible to eliminate risk, the employer is obliged to ensure the use of the provided personal protective equipment and continuously and effectively check whether this equipment is utilised [1].

Vibration and noise pose risks in the working environment, as they negatively affect working conditions and workers' health. Preventive measures should be taken against these risks. Vibration can be separated into two categories: hand-arm vibration and whole-body vibration. As defined in the National Vibration Regulation, "hand-arm vibration" means mechanical vibration that poses a risk to the health and safety of the workers and primarily leads to vascular, bone, joint, nerve, and muscle disorders when transferred to the hand-arm system. Whole-body vibration occurs when mechanical vibrations are transferred to the whole body, which poses risks to the workers' health and safety and frequently leads to discomfort in the back and trauma in the spine [2].

In many workplaces, whole-body vibration is not considered to be a serious problem, and many occupational health and safety experts are inexperienced regarding preventive measures despite the observed negative health outcomes [3]. Exposure to vibration results in disturbances to working comfort decreases in the productivity of the workforce, and negative effects on the physiological functions of the workers. Intense exposure to vibration can cause occupational illnesses, the most frequently encountered and deeply investigated of which is lower back pain; it is known that exposure to whole-body vibration leads to lower back pain. High-frequency vibrations affect both the physiological and mental health of workers. Experiencing continuous vibrations in their working environment makes workers tired and nervous. The fatigue, nervousness, and physiological health problems of people exposed to vibration also make them prone to accidents [4, 5, 6].

The International Labour Organisation (ILO) defined noise as "all sound which can result in hearing impairment or be harmful to health or can otherwise be dangerous" [7]. Noise arising in the workplace negatively affects the workers' hearing and general perception, disturbs their physiological and psychological balance, decreases productivity, and increases the frequency of accidents in the workplace. When noise levels in a workplace are decreased, the difficulty of the work decreases, productivity increases, and workplace accidents decrease [8, 9].

Noise and vibration are intense in the metal industry due to the conditions of the workplaces and the processes employed. With this knowledge, a study was performed in a metal processing plant to understand the current situation with respect to noise and vibration and reveal the risks posed to occupational health and safety. In this study, the results of measurements determined the locations of high-risk areas in the plant and established the exposure levels experienced by the workers. The aim of this study was to attract attention to the subjects of noise and vibration in the workplace, which pose risks to occupational health and safety in similar plants, and thereby contribute to the body of research in the field of occupational health and safety.

## 2. Methods

**2.1. Determination of the Measurement Areas in the Plant –** Due to the nature of the production process, different levels of noise and vibrations spread from various machines in the workplace. To determine whether or not the technicians working in the production areas were exposed to any vibration or noise, a risk determination study was performed according to the Guide to Good Practice on Whole Body Vibration [10]. A risk assessment table (Table 1) was prepared using the observations of the current situations in the production areas. Vibration and noise measurement locations in the production area were determined according to the risk assessment table. The ground plan of the plant and the measurement locations are presented in Figure 1. Due to the nature of the work performed in the production area, no exposure to hand-arm vibration was observed, but there was exposure to whole-body vibration. Measurements were performed at all measurement locations indicated in Table 1 except for Quality Station-6, where nobody was working.

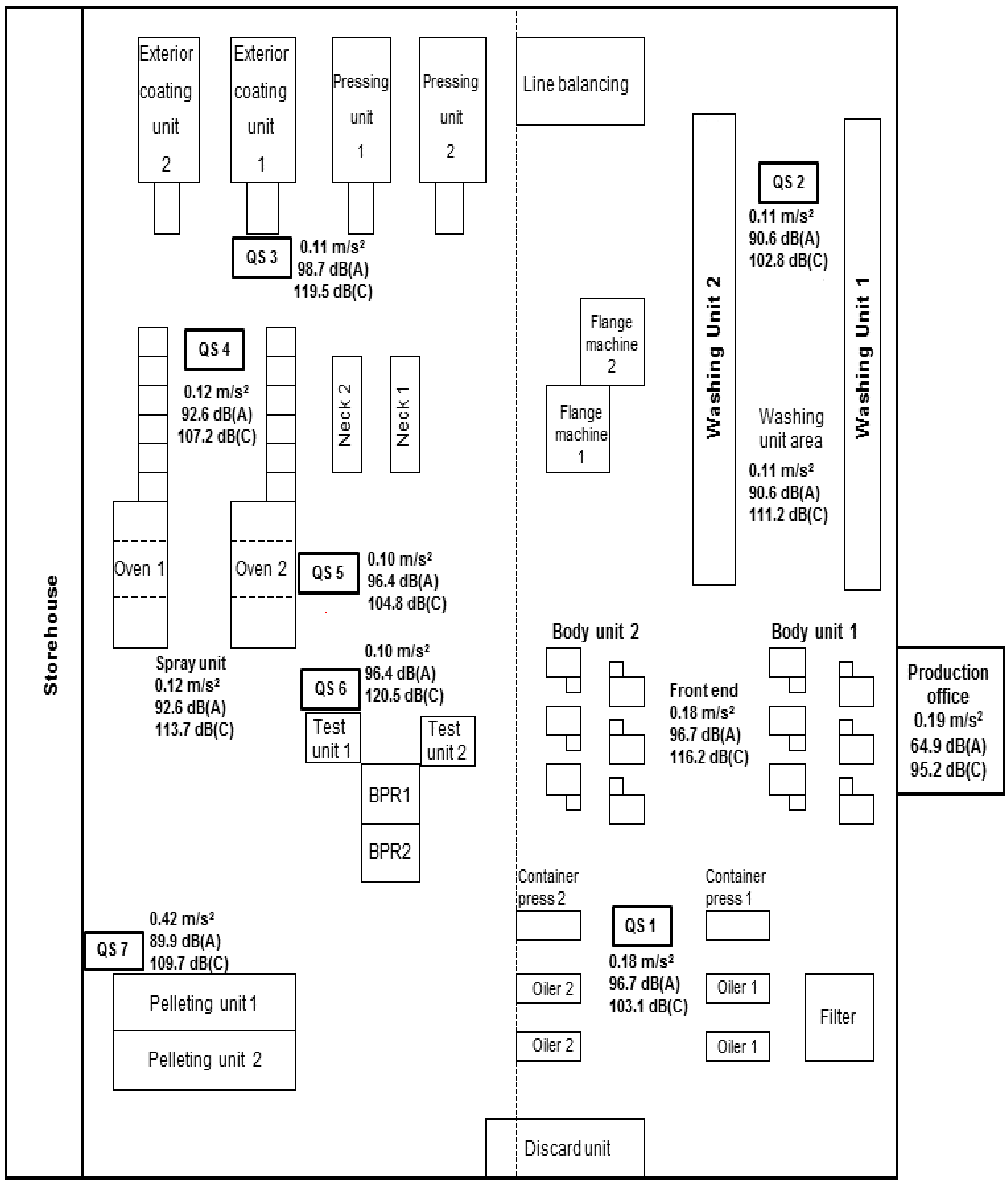


**Figure 1: Noise and vibration measurement locations and values in the production area.**

**Table 1: Production area risk assessment table**

| Measurement Area | Is There Anyone Working in the Area? | | Working duration (hour) | Is Vibration Being Felt? | | Type of Exposure to Vibration | | Is There Any Protection Against Vibration? | Is There Any Noise? | | Is There any Personal Protective Equipment for Noise? |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | | Yes | No | Hand / Arm | Whole Body | | Yes | No | |
| Production Office | □ | | 7.5 | □ | | | □ | Separated by a wall from the production area | □ | | Ear protectors, obligatory |
| Front end Quality Station 1 | □ | | 4 | □ | | | □ | Separated by PVC panels from the production area | □ | | Ear protectors, obligatory |
| Front end Front of the Body Unit | □ | | 3.5 | □ | | | □ | No | □ | | Ear protectors, obligatory |
| Washing Unit Quality Station 2 | □ | | 4 | □ | | | □ | Separated by PVC panels from the production area | □ | | Ear protectors, obligatory |
| Washing Unit Area | □ | | 3.5 | □ | | | □ | No | □ | | Ear protectors, obligatory |
| Pressing Unit Quality Station 3 | □ | | 7.5 | □ | | | □ | No | □ | | Ear protectors, obligatory |
| Spray Unit Quality Station 4 | □ | | 4 | □ | | | □ | Separated by PVC panels from the production area | □ | | Ear protectors, obligatory |
| Spray Unit Area | □ | | 3.5 | □ | | | □ | No | □ | | Ear protectors, obligatory |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Back End Quality Station 5 | □ | | 7.5 | □ | | | □ | Separated by PVC panels from the production area | □ | | Ear protectors, obligatory |
| Beck end Quality Station 6 | | □ | 0 (Unmanned area) | - | | | - | No (Unmanned area) | - | | Ear protectors, obligatory |
| Pelleting Unit Quality Station 7 | □ | | 7.5 | □ | | | □ | No | □ | | Ear protectors, obligatory |

**2.2. Vibration Measurement in the Plant –** The whole-body vibration exposure experienced in the workplace was defined to be either the maximum value of the root mean squared (rms) vibration, defined in terms of the equivalent continuous acceleration experienced over a given eight-hour work period A(8), or the highest vibration dose value (vdv) of the frequency-weighted accelerations. Daily exposure values were determined using the standards defined in Turkish Standards (TS) 2775 "Guide for Evaluation of Human Exposure to Whole Body Vibration" [11], TS International Organisation for Standardisation (ISO) 2631-2 "Evaluation of the Human Exposure to Whole Body Vibration – Part 2: Continuous and Shock-Induced Vibration in Buildings (1-80 Hz)" [12], and the "Guide To Good Practice On Whole Body Vibration" [10]. The exposure levels were evaluated using information from the user's guide for the equipment that sourced the vibration and the measurements made in this study.

Sound- and vibration-level measurements were performed with a Svantek 947 device. The axis-specific accelerations were detected by placing the vibration-sensitive pad on the floor and were transmitted to the device controller. Daily vibration exposures were calculated in terms of A(8) in $m/s^2$ using the accelerations measured along the x, y, and z axes.

**2.3. Noise Measurement in the Plant –** The noise levels experienced in the workplace were measured according to standards defined in the Noise Regulation [13], the Turkish Standards Institution (TSE) 2607 ISO 1999 "Acoustics - Determination of occupational noise exposure and estimation of noise-induced hearing impairment" [14], and TSE 2673; "Acoustics - Guide To The Measurement of Airborne Acoustical Noise and Evaluation of its Effects on Man" [15]. The sound levels were measured as Leq in dB(A) with a Svantek 947 sound level measurement device placed at ear level. Personal exposure values were calculated using the highest sound pressure Ppeak (the maximum value of the instantaneous noise pressure, computed with frequency weight C) and the Daily Noise Exposure Level ($L_{EX,}$ 8h) (dB(A) re.20 □Pa). To determine the exposure that actually affects the workers, the exposure limit value considers the protective effect of the personal ear protectors that the workers use. However, the effect of the ear protectors was not taken into account when computing the effective exposure values.

## 3. Result and Discussion

**3.1. Evaluation of the Vibration Measurement Results in the Plant –** The axis-specific accelerations obtained to determine the Whole-Body Vibration to which the workers were exposed in the measurement locations (Figure 1) and the corresponding personal exposure A(8) values are given in Table 2. The personal exposure values obtained at all locations where vibration measurements were performed are lower than the effective daily exposure limit of 0.5 $m/s^2$ defined in the relevant regulation.

**Table 2: Vibration levels detected in the plant, exposure times, and personal exposure levels**

| Measurement Area | Exposure Type | Vibration levels rms, m/s$^2$ | Exposure Time (hour) | Personal Exposure Levels A(8), m/s$^2$ |
|---|---|---|---|---|
| FRONT END (FRONT OF THE BODY UNIT) | Whole body vibration ( Foot ) | X axis: 0.091<br>Y axis: 0.120<br>Z axis: 0.270 | 3.5 | 0.18 |
| FRONT END (QUALITY STATION 1) | Whole body vibration ( Foot ) | X axis: 0.075<br>Y axis: 0.078<br>Z axis: 0.065 | 4 | 0.18 |
| PRODUCTION OFFICE | Whole body vibration (Top of stool) | X axis: 0.138<br>Y axis: 0.092<br>Z axis: 0.200 | 7.5 | 0.19 |
| WASHING UNIT (QUALITY STATION 2) | Whole body vibration ( Foot ) | X axis: 0.044<br>Y axis: 0.070<br>Z axis: 0.044 | 4 | 0.11 |
| WASHING UNIT (AREA) | Whole body vibration ( Foot ) | X axis: 0.067<br>Y axis: 0.091<br>Z axis: 0.110 | 3.5 | 0.11 |
| PRESSING UNIT (QUALITY STATION 3) | Whole body vibration ( Foot ) | X axis: 0.060<br>Y axis: 0.080<br>Z axis: 0.100 | 7.5 | 0.11 |
| SPRAY UNIT (QUALITY STATION 4) | Whole body vibration ( Foot ) | X axis: 0.045<br>Y axis: 0.050<br>Z axis: 0.055 | 4 | 0.12 |
| SPRAY UNIT (AREA) | Whole body vibration ( Foot ) | X axis:0.088<br>Y axis: 0.098<br>Z axis: 0.170 | 3.5 | 0.12 |
| BACK END (QUALITY STATION 5) | Whole body vibration ( Foot ) | X axis: 0.039<br>Y axis: 0.066<br>Z axis: 0.042 | 4 | 0.10 |
| BACK END (QUALITY STATION 6) | Whole body vibration ( Foot ) | X axis: 0.055<br>Y axis: 0.082<br>Z axis: 0.075 | 3.5 | 0.10 |
| PELLETING UNIT (QUALITY STATION 7) | Whole body vibration ( Foot ) | X axis: 0.150<br>Y axis: 0.160<br>Z axis:0.430 | 7.5 | 0.42 |

**3.2. Evaluation of the Noise Measurement Results in the Plant –** The noise levels Leq dB(A) and Ppeak dB(C) values determined at the measurement locations (Figure 1) and the corresponding personal exposure values ($L_{EX,}$ 8h) calculated using these values are given in Table 3.

When the daily personal exposure values ($L_{EX,}$ 8h) calculated for the plant are compared to the highest effective exposure values permitted by the Noise Regulation [13], it was found that the personal exposure levels exceeded the limit of 85 dB(A) at all measurement locations other than the Production Office. In contrast, the Ppeak values obtained at the measurement locations were compared to the highest effective exposure value of Ppeak = 140 μPa = 137 dB(C), and it was found that the Ppeak values obtained at all measurement locations were lower than the limit defined in the regulation.

**Table 3: Equivalent noise levels, exposure times, Ppeak values, and personal exposure values in the plant**

| Measurement Area | Exposure Time (hour) | Equivalent Noise Level Leq, dB(A) | Ppeak value dB(C) | Personal Exposure ($L_{EX}$, 8h) (dB(A) re.20 µPa) |
|---|---|---|---|---|
| FRONT END (FRONT OF THE BODY UNIT) | 3.5 | 100.2 | 116.2 | 96.7 |
| FRONT END (QUALITY STATION 1) | 4 | 79.4 | 103.1 | |
| PRODUCTION OFFICE | 7.5 | 65.2 | 95.2 | 64.9 |
| WASHING UNIT (QUALITY STATION 2) | 4 | 79.8 | 102.8 | 90.6 |
| WASHING UNIT (AREA) | 3.5 | 94 | 111.2 | |
| PRESSING UNIT (QUALITY STATION 3) | 7.5 | 99 | 119.5 | 98.7 |
| SPRAY UNIT (QUALITY STATION 4) | 4 | 83.6 | 107.2 | 92.6 |
| SPRAY UNIT (AREA) | 3.5 | 95.9 | 113.7 | |
| BACK END (QUALITY STATION 5) | 4 | 85.2 | 104.8 | 96.4 |
| BACK END (QUALITY STATION 6) | 3.5 | 99.8 | 120.5 | |
| PELLETING UNIT (QUALITY STATION 7) | 7.5 | 90.1 | 109.7 | 89.8 |

**4. Conclusion –** The personal exposure A(8) values obtained using the vibration measurements are smaller than the effective exposure limit of 0.5 m/s² for whole-body vibration permitted by the National Vibration Regulation, and this shows that there is no risk to the workers due to whole-body vibration exposure.

However, noise levels between 64.9 – 98.8 dB(A) in terms of $L_{EX,}$ 8h were observed. The highest effective exposure value permitted by the National Noise Regulation is $L_{EX,}$ 8h = 85 dB(A). The personal exposure levels exceeded this limit at all measurement locations except for the production office. The noise level in the production office is lower than the threshold value because the production office is isolated from the production area by PVC panels. The areas named "quality areas" are open areas in which no form of isolation was present to decrease the noise level. Isolation cannot be performed in these areas because active movement involving working with the machines occurs in these open areas.

These results indicate that the negative effects of noise should be minimised by isolating the noise and/or using personal protective equipment. The plant managers should prioritise regular risk assessments in the plant, perform noise level measurements periodically and after each change to any processes or equipment, and ensure the use of more advanced ear protection equipment.

Because various personal ear protection devices are designed for use in environments with different noise characteristics, it is crucial to select the most appropriate of these devices. Attention should be paid to ensure that the users do not use ear protection with unnecessarily strong attenuation capabilities, as these types of ear protectors may lead to difficulties in hearing important warning signals in the plant, and the users may not feel comfortable or may feel isolated from the environment. To correctly select ear protection, it is necessary to calculate the attenuation using the manufacturer's data and ensure that the selected equipment fulfils the specific attenuation requirements of a given worker.

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